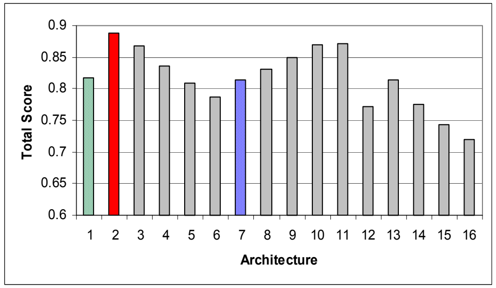
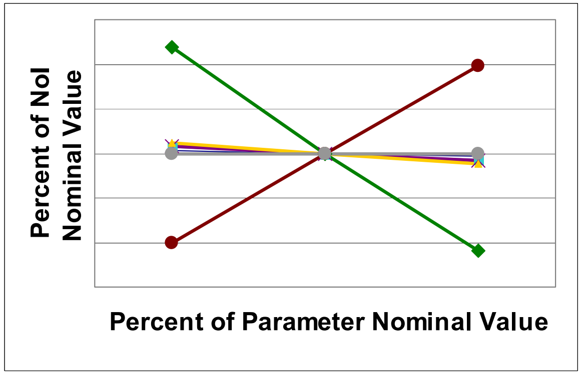
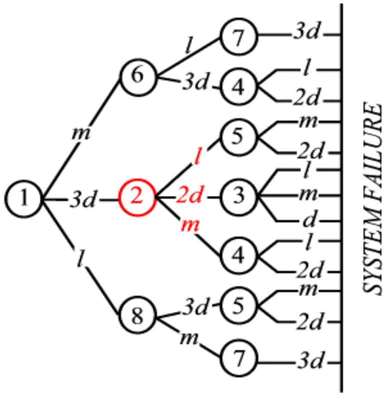
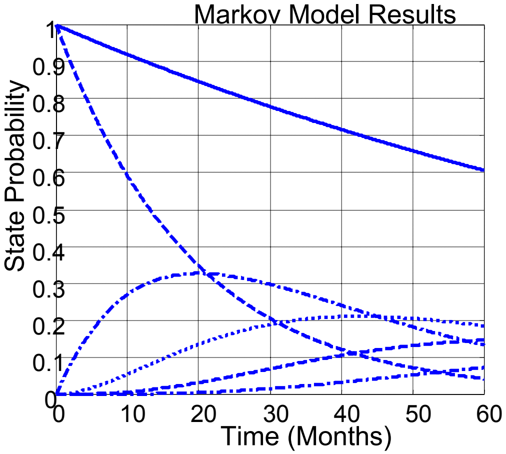
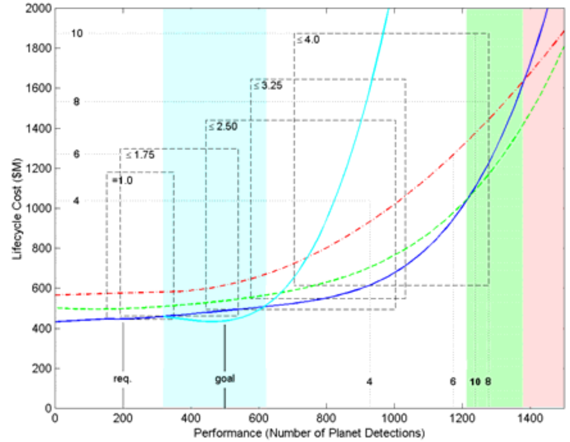


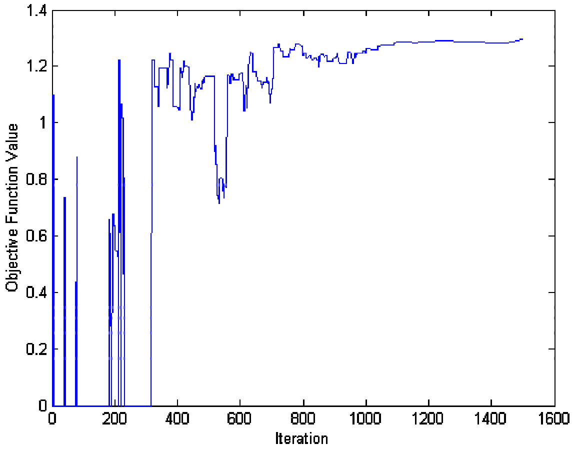




Architectural Trade Models







Risk and Reliability Analysis

- Risk and reliability are beginning to be recognized as key parameters to a design
  - Affect the cost, value, and perceived value of any mission
- As systems become more complex, engineering judgment is no longer sufficient to understand how failures of different components in the system will affect the total system performance
- Decisions made early in the design process have a large effect on overall cost, risk, and performance
  - How do you analyze the risk or reliability of a design when you don't have the full design yet?
- Case study of Terrestrial Planet Finder (TPF) mission

"It is the nature of probability that unlikely things will happen."

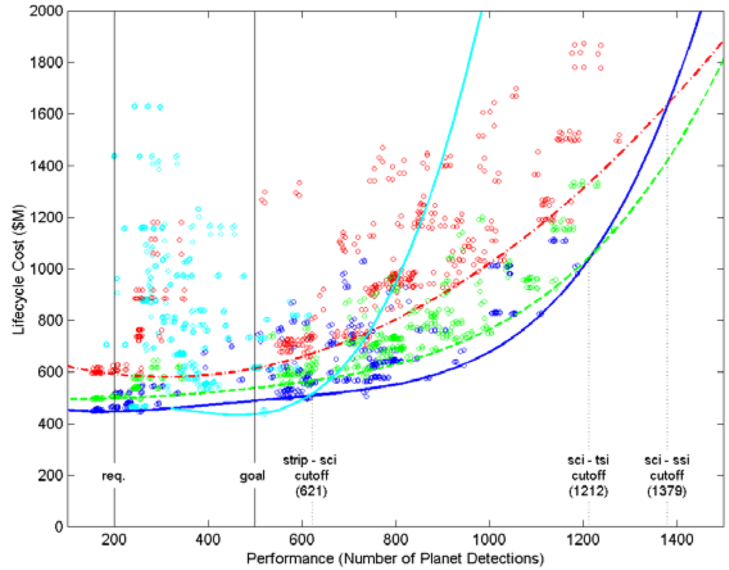
- Aristotle

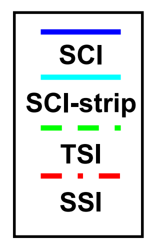
What is the best way to bring risk and reliability analysis into the design process at an earlier stage of design?

GINA: A Systems Approach to TPF

- Generalized Information Network Analysis (GINA) methodology
  - A systems engineering and architecting methodology, based upon information network theory, that facilitates quantitative comparisons between viable architectures competing to satisfy a mission's needs
- Comprehensive Metric Set
  - Capability "Quality of Service" Metrics
    - Isolation - ability to separate the desired signal from competing signals
    - Integrity - quality of signal characterized by noise or anomalies
    - Rate - throughput of the system
    - Availability - temporal and spatial variability of isolation, integrity & rate
  - Evaluation Metrics
    - Performance - productivity over mission lifetime in presence of failures
    - Cost per Function - mission efficiency: lifecycle cost per performance
  - Adaptability - sensitivity analysis

Example Results



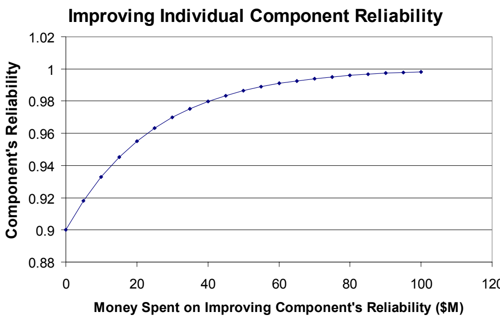


Influence of Interferometer type
Interferometer type is influential in cost but not in performance. Hence the vertical (and not horizontal) separation of the pareto fronts.

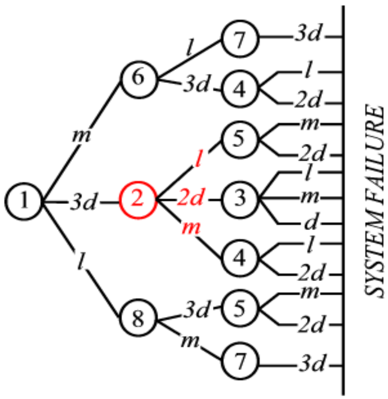
- GINA derives these metrics from physics models

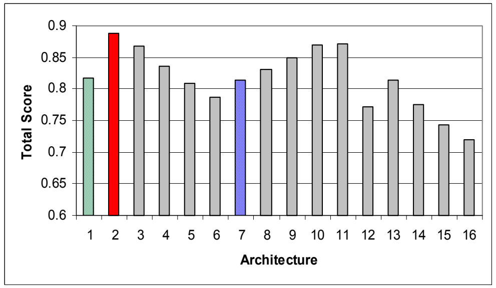
Resource Allocation

In a complex network, where should funds be spent to either add redundancy or improve a component's reliability such that the system's lifecycle metrics can be improved most cost effectively?



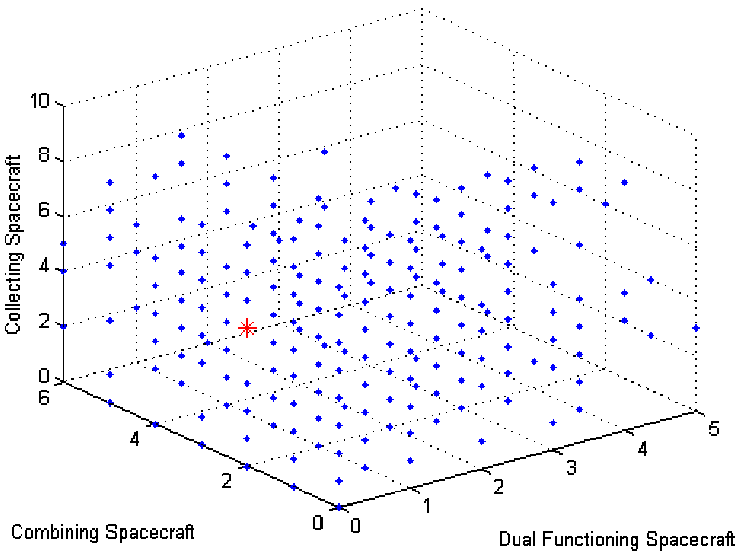
- **Use exponential function to model increased reliability with $ spent**
- **Architecture defined in terms of both the number of each type of spacecraft and the amount of money spent to improve the reliability of each type of subsystem**
- **High level productivity, reliability, and cost models developed**
  - Reliability model based on failure rates and Markov model
  - Productivity model based on number of collectors
  - Cost model based on learning curve savings and complexity
  - Productivity and cost modeled for each state
- **Automated Markov modeling process developed to analyze each architecture taking failures into account**
- **Heuristic optimization schemes used to find "optimal" architectures**

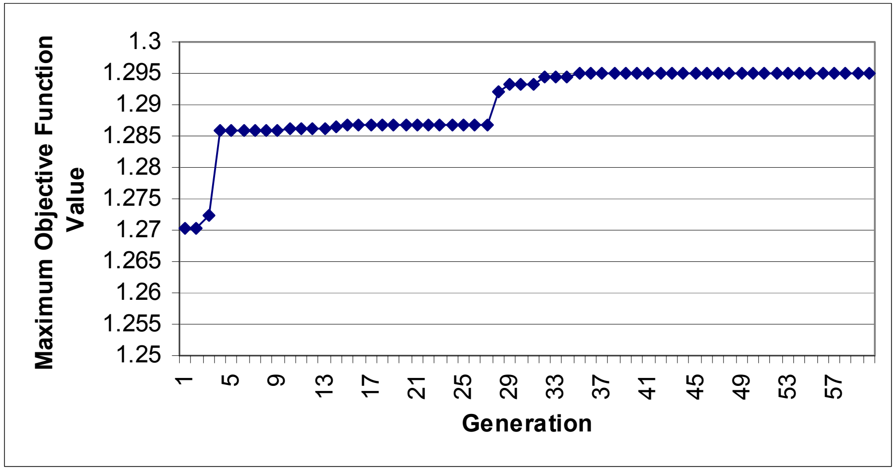




Resource Allocation Results

- Example results
  - Genetic Algorithms
- "Best" Architecture
  - 0 dual functioning spc.
  - 2 combining spc.
  - 5 collecting spc.
  - $12M on improving combining optics reliability
  - $9M on improving collecting optics reliability
  - $25M on improving bus reliability
- ~250 solutions within 99% of optimal
  - Only vary by division of money
- 7 solutions within 97.5% of optimal solution obj. func. w/ at least one number of spc. different from "optimal" solution





Failures in Path Dependant Systems

- How to model time and path dependant activities in the presence of failures?
  - In previous work the productivity of the system depended only on the state the system was in
    - All stars assumed to be at 10 parsecs
  - In reality, the productivity of the system depends on the state of the system and the particular star the system is observing
    - Stars at further distances take longer to integrate
    - Can't just multiply productivity of each state by probability in that state for each time step anymore because the productivity in that state depends on where in the star list you are, which in turn depends on the integration time of the previous stars, and therefore the previous states of the system
  - System still follows Markov process rules, but productivity is now path dependant
  - Monte Carlo simulations will capture this effect, but take a long time to run
    - Is there a more efficient way to model the productivity of these systems?

Failures in Path Dependant Systems – Preliminary Approach and Results

Approach

1. Use Markov modeling to find P, probability of being in each state at each time-step
2. For each star:
    1. Find the integration time in each state (distance dependant)
        1. Including overhead time
    2. Based on the probability of being in each state at the beginning of the image and the time to take the image in each state, find the expected number of time steps to complete the image
        1. Normalize probabilities based on only those states in which taking an image is possible
            1. i.e. if there is a 1/3 chance the system is in state 1, a 1/3 chance the system is in state 2, and a 1/3 chance the system has failed completely then the expected number of time-steps would be ½*time-steps(1) + ½*time-steps(2)
    3. For each time-step up to the expected number of time-steps, find the expected number of images per state using un-normalized probabilities of being in each state
    4. Sum up the expected number of images over all states over the expected number of time-steps
3. Update the clock by the expected number of time-steps
4. If time is less than the lifetime, move on to the next star and repeat

Results

- Use a Monte Carlo simulation as "truth"
- Test against the path-independent approach used previously, with the time to take an image found based on the average distance to the stars in the star-list
- Path-dependant method is an average of 5.2% off from the Monte Carlo "truth", compared to an average of 13.4% off for the path-independent method